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MINISTRY OF TECHNOLOGY

SMRE

RESEARCH REPORT

274

ANTI-SLIP STUDS FOR SAFETY FOOTWEAR

H.T. RAMSAY AND C.R. SENNECK

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MINISTRY OF TECHNOLOGY

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Organized and continuous research to improve the safety of British coal miners had its beginnings in a research organization which was founded in 1908 and which, in the course of time, became the Safety in Mines Research Establishment. SMRE conducts research on major problems affecting the safety and health of coal miners. Accounts of the work are published in Research Reports and in articles in the scientific and technical press. Progress reports, and accounts of recent developments, together with synopses of recently published papers, are given in "Safety in Mines Research", which is the title of the Annual Report of SMRE. A record of work published since 1908 is given in the "SMRE Bibliography (Third Edition) 1966" and a list of SMRE Research Reports is available on application to the Sheffield address.

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Anti-slip studs for safety footwear

H.T. Ramsay and C.R. Senneck

SMRE Research Report No.274 1970 12 pages 1 illus. Price 4s. 5d [22p]

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Report available from:- Safety in Mines Research Establishment, Ministry of Technology, Administration and Central Laboratories, Red Hill, off Broad Lane, Sheffield, S3 7HQ

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Research Report 274

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H.T. Ramsay, C.B.E., M.Sc.(Eng), F.Inst.P., M.I.MIN.E.
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SUMMARY

A large and increasing proportion of the accidents occurring in British mines are caused by men losing their balance, and there is evidence that slipping plays a major part in many such accidents.

Simple laboratory measurements of the frictional force between footwear and different floor materials with different surface conditions showed that existing types of miners' footwear did not give a good grip in all circumstances. In particular, although rubber-soled footwear gave an excellent grip on clean surfaces, it gave a very much reduced grip on greasy or muddy surfaces. An unexpected change in grip could cause men to slip.

Boots fitted with tungsten carbide tipped studs, such as are fitted to tyres for motoring on ice, were tested and gave a reasonable grip which was almost unaffected by the condition of the surface. User trials of such studded boots have been encouraging and are being extended, most wearers being enthusiastic about the boots' anti-slip properties.

Extensive tests are in progress on the frictional-ignition hazard presented by tungsten carbide tipped studs. It seems likely that the hazard will prove to be in the same low range as that given by hobnails and other steel fittings to footwear.

Advice is given on where and how to insert studs into existing footwear and suggestions are made for future developments.

The publication of the early results of the work has produced a lot of inquiry from industries other than coalmining and this brief report has been prepared to meet the needs of these other industries.

1. INTRODUCTION

National statistics for British coal mines show that a fifth of the underground accidents for which industrial injury compensation is paid are placed in the "stumbling, falling or slipping" category and the proportion is rising year by year. On the surface of collieries, a third of all compensable accidents and almost a third of the "reportable" accidents (i. e. those involving injuries roughly equivalent in severity to at least the fracture of a major bone) are placed in the "stumbling, falling or slipping" category, and again the proportions are rising. Loss of balance is thus a major source of injury in British coal mines.

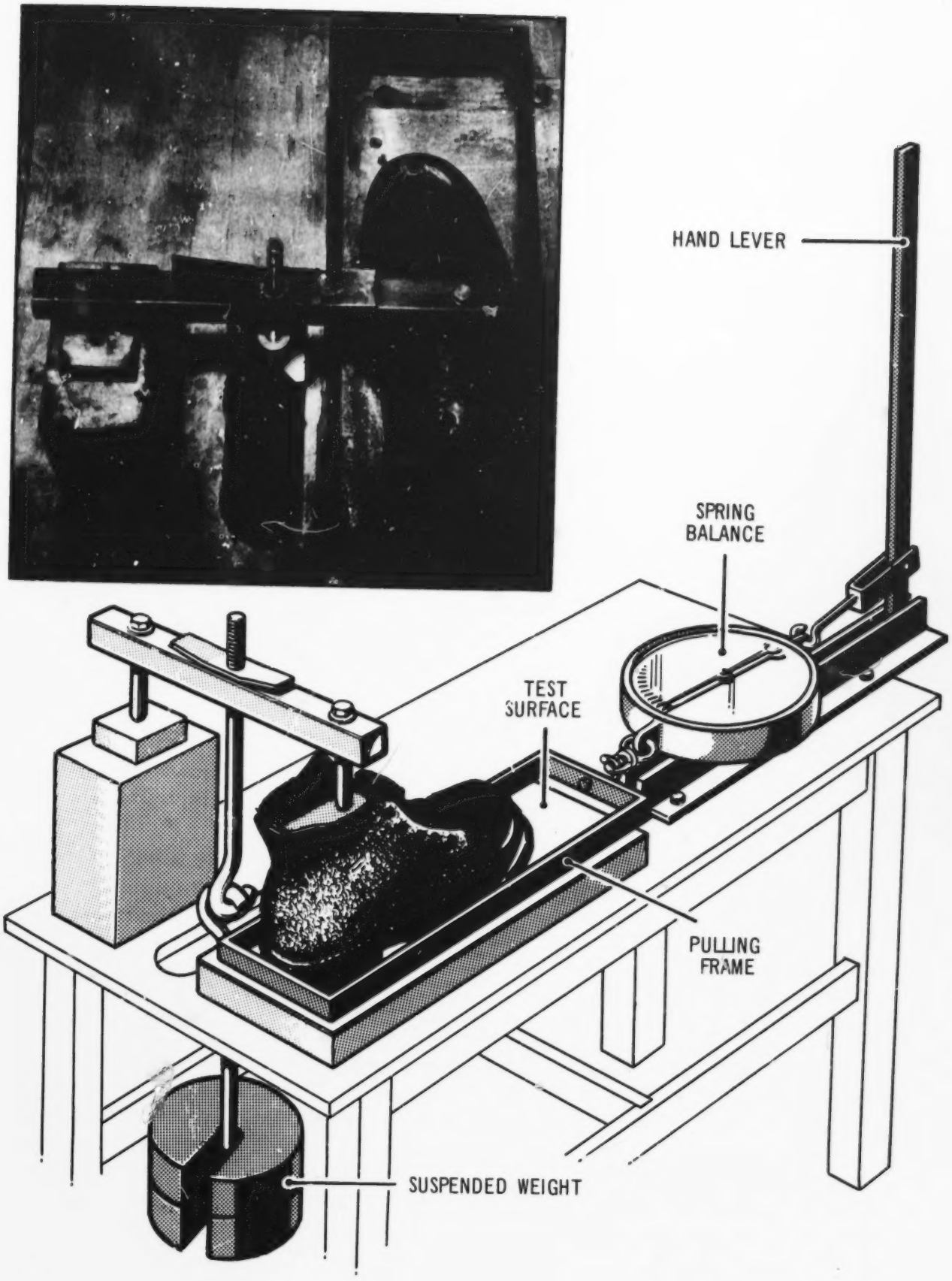

Fig. 1 – Apparatus for determining the effective grip of a boot

Published statistics give no indication of how many "stumbling, falling or slipping" accidents are caused by slipping as opposed to the many other possible ways in which a man can lose his balance, but data assembled by SMRE suggest that slipping is a very common cause. A quick, exploratory investigation of the friction between footwear and floor was indicated.

2. LABORATORY TESTS

2.1 Experimental arrangements - It was decided at the outset that the tests should be kept simple and that no attempt should be made to simulate the complex motions and forces involved in walking. Accordingly, the test apparatus shown in Fig. 1 was constructed.

A vertical load was applied to the boot *via* a wooden shoemakers' last (to a point above the centre of the instep). The boot was then pulled with a steadily increasing horizontal force by a hand lever attached to a frame around the boot. A spring balance was connected between the lever and the frame to show the horizontal force when the boot just slipped. Preliminary tests showed that the effective coefficient of friction, obtained by dividing the critical horizontal force at which slipping just occurred by the vertical load, did not vary greatly for vertical loads in the range 111 to 667 N (25 to 150 lbf). All subsequent tests were done with a vertical load on the boot of 334 N (75 lbf), approximately half the weight of a man.

Three surface materials commonly met with in collieries were used: smooth mild steel, concrete, and PVC-covered conveyor belting. Each surface was tested in a number of conditions: dry and clean; clean but wet; covered with a transparently thin smear of a mixture of coal dust and mud which, in bulk, was wet enough to hold together but not to drip; covered with a 3 mm (0·12 in) layer of yellow clay mixed with water to the consistency of plasticine; and coated with a standard motor grease.

For each of these surfaces and conditions, measurements of the horizontal force needed to produce slipping were made with a miners' hobnailed leather-soled boot; a safety wellington with deep cleats running to the edge of the sole; a miners' safety boot with a direct-moulded rubber sole; and a wooden clog from which the steel plates had been removed. Each measurement was performed ten times by each of two operators. The average of the twenty readings was divided by the value of the vertical force applied to the footwear, to give an effective coefficient of friction (henceforth referred to as "grip") for each combination of footwear, surface material, and surface condition.

2.2 Grip of conventional footwear - The results obtained with the four types of footwear tested are shown in Tables 1 to 4.

TABLE 1

Grip of hobnailed boot

Surface material	Condition of surface				
	Clean, dry	Clean, wet	Smear of coal dust and mud	Heavy clay	Grease
Steel	0·2	0·2	0·3	0·5	0·2
Concrete	0·5	0·5	0·3	0·5	0·4
PVC belting	0·6	0·7	0·3	0·3	0·4

TABLE 2

Grip of wellington

Surface material	Condition of surface				
	Clean, dry	Clean, wet	Smear of coal dust and mud	Heavy clay	Grease
Steel	0·5	0·6	0·4	0·2	0·2
Concrete	0·7	0·9	0·4	0·3	0·2
PVC belting	1·4	0·9	0·3	0·2	0·2

TABLE 3

Grip of rubber-soled safety boot

Surface material	Condition of surface				
	Clean, dry	Clean, wet	Smear of coal dust and mud	Heavy clay	Grease
Steel	0·8	0·7	0·2	0·2	0·1
Concrete	0·8	0·8	0·4	0·2	0·3
PVC belting	1·2	0·9	0·3	0·1	0·1

TABLE 4

Grip of wooden clog

Surface material	Condition of surface				
	Clean, dry	Clean, wet	Smear of coal dust and mud	Heavy clay	Grease
Steel	0·4	0·6	0·4	0·4	0·2
Concrete	0·4	0·7	0·4	0·4	0·4
PVC belting	0·9	0·7	0·5	0·3	0·2

From these results it is clear that, under the test conditions, the hobnailed boot gave a relatively poor grip, particularly on steel, and that its grip did not vary greatly with the condition of the surface beneath it. The rubber-soled boot and, to a lesser extent, the wellington gave an excellent grip on clean, dry surfaces and, except on PVC belting, the grip did not deteriorate when the surface was wet but otherwise clean. However, when there was even the thinnest smear of moist contaminant the grip of these rubber-soled specimens became very much lower and, for most of the contaminated surfaces tested, was lower than the grip given by the hobnailed boot. The wooden clog gave results intermediate between the hobnailed and rubber-soled boots in both clean and contaminated conditions. In general terms, the better the grip was in clean conditions, the worse it became when the surface was contaminated by a lubricating layer.

In mining, and doubtless in many other industrial situations, such lubricating layers are not infrequent. It seems likely that the greatly reduced grip given in such conditions by modern rubber-soled footwear, together with their reassuringly good grip in clean or dry conditions, creates a significant slipping hazard for men who walk unknowingly onto a muddy or greasy patch.

This potentially dangerous change of grip might be avoided if one could arrange for footwear to bite through a lubricating layer and into the underlying hard substrate. To achieve this penetration, protuberances of a very hard substance would be required and the body weight would have to be concentrated on a very small area so as to produce high localized pressure. The protuberances would also have to be hard wearing in order to retain their effectiveness. Tungsten carbide tipped studs, such as are used for motoring on ice, meet these requirements and are also readily available and designed for inserting into rubber.

2.3 Grip of boots fitted with tungsten carbide tipped studs - A rubber-soled miners' safety boot similar to that which gave the results shown in Table 3, but with seven tungsten carbide tipped studs inserted into the sole and five into the heel, was therefore tested in the same way as before. The results obtained are shown in Table 5.

TABLE 5

Grip of rubber-soled boot fitted with studs

Surface material	Condition of surface				
	Clean, dry	Clean, wet	Smear of coal dust and mud	Heavy clay	Grease
Steel	0·4	0·4	0·5	0·6	0·4
Concrete	0·6	0·7	0·6	0·6	0·6
PVC belting	0·9	0·8	0·6	0·6	0·6

While the studded boot did not give as good a grip as the unstudded boot or the wellington on clean surfaces, it gave a markedly better grip on contaminated surfaces; and it gave a better grip than the hobnailed boot on all surfaces. The fact that the studded boot gave a reasonably good grip which was almost independent of the presence or absence of lubricating contaminants suggests that a man wearing studded boots would be much less likely to slip through walking unexpectedly on a muddy or greasy patch than a man wearing unstudded rubber-soled footwear.

3. STUDS AND STUDDING

3.1 Available studs - Tungsten carbide tipped studs are commercially available in sizes suitable for use in tyres of vehicles ranging from motor cars to earth-moving equipment. Clearly, only the smaller end of the range of available sizes is of interest for use in footwear. A typical stud designed for use in car tyres consists of a 2·5 mm (0·1 in) diameter cylinder of tungsten carbide brazed into, and projecting slightly from, a mild steel body that has one or two flanges to help anchor it in the rubber. Studs with a single flange are available down to 9 mm (0·35 in) overall length, while double-flanged studs are available down to 11 mm (0·43 in) overall length.

3.2 Suitability of footwear for studding - The studs should be inserted so that they project about 1·5 mm (0·06 in) from the rubber, very slightly more than is usual in car tyres. If the studs project more than this amount the increased leverage tends to make their retention less certain, while a smaller projection makes it difficult to ensure that the bulk of the body weight is supported by studs rather than by rubber.

Stud manufacturers suggest that there should be a minimum of 3 mm (0·12 in) of rubber between the tyre cord and the base of a stud. Experience with boots suggests that a similar minimum thickness of rubber between the insole and the base of a stud is satisfactory and does not result in complaints of uncomfortable local pressure on the foot.

Thus, allowing 0·5 mm (0·02 in) for random variations in stud depth, studs should not be inserted in footwear where the depth of rubber in the sole (or heel) is less than 2·0 mm (0·08 in) greater than the overall length of the stud.

Stud manufacturers recommend that the small studs being considered here should only be inserted into tyres at places where there is a block of rubber at least 12 mm (0·47 in) square. While studs can be inserted into boot soles having ribs less than 12 mm wide, they are less likely to remain in place than studs with more rubber around them.

3.3 Location of studs - Given footwear with an adequate sole thickness and sufficiently large raised areas in the tread pattern, the problem arises of how many studs to insert and where to place them. About twelve studs per boot, with seven

or eight in the sole and five or four in the heel, gives a reasonable compromise between grip and cost. The weight of twelve typical twin-flanged 11 mm (0·43 in) studs is 22·5 g (0·05 lb), so that twelve studs increase the weight of a standard miners' boot by between two and three per cent.

The studs should be positioned so that there is an adequate amount of rubber around them and so that the minimum area of rubber touches the ground when the boot is worn, the object being to support the wearer's weight on the studs. A simple way of deciding on a suitable stud layout is to stick small washers, 1·5 mm (0·06 in) thick, to the sole and heel and adjust their positions until, when the boot is rocked about on a flat surface, no rubber touches the surface. The washers then mark the places where studs should be inserted in that type of boot.

3.4 Studding procedure - Studs can be inserted into footwear in exactly the same way, with the same equipment, as they are inserted into tyres. Thus, at present, the most economical way of getting a few pairs of boots studded is to arrange for the studs to be inserted by a local garage that offers a tyre-studding service.

Where a stud is to be inserted, a hole is drilled to a predetermined depth which depends on the length of the stud to be used and, to some extent, on the properties of the rubber. The hole is drilled with a high speed drill and a special bit. The three jaws of a special compressed-air "gun" are then inserted into the hole; the trigger is pressed, and a piston forces the jaws apart, pushes a stud into the enlarged hole, and ejects the gun from the hole. The rubber then contracts back around the stud and holds it firmly in place.

High-speed films of the studding process made by SMRE show that if the jaws of the gun are not lubricated, for example by dipping them in a weak solution of washing-up fluid in water, the extended jaws tend to drag up rubber from the sides of the hole as the piston, pressing down on the stud, forces the jaws out of the hole. This can result in cracks developing in the rubber around the stud. The high-speed films also showed that, if the gun is pressed into the hole with excessive force, there is a tendency for the extended jaws to bounce back and dig into the rubber immediately after being ejected from the hole. However, provided that the jaws of the gun are kept lubricated and excessive force is not exerted on the gun, the studding process is quick, easy and reliable.

The drilling of the hole takes longer and is more likely to give rise to trouble. Each of the following conditions appears to be essential for successful drilling: high speed of rotation (ca. 5 000 r. p. m.); sharp drill bit; and slow insertion of the drill into the rubber so that the bit cuts rather than forces its way in. Failure in any one of these respects can cause cracks to appear in the rubber surrounding the stud. It is also important that the protrusion of the drill bit from the depth-regulating collet is set correctly each time a new drill bit is fitted.

4. IGNITION HAZARD

It is well known that the combination of tungsten carbide and sandstone rocks can readily produce ignition of methane when the forces, speeds and durations involved reach the scale commonly met in coal or rock-cutting. Since the hazard is related to the level of the mechanical power involved, it is important to know whether the effort that can be expended by a human being is adequate to produce a serious sparking hazard.

At the time of writing, an extensive series of tests is being made with a machine in which the material under test is made to give a powerful glancing blow to a block of sandstone in the presence of an explosive mixture of methane/air. The setting of the machine is such that it is believed to deliver a much more incendive blow than can be achieved by ordinary human effort.

While the tests are still at too early a stage for firm conclusions to be drawn the evidence so far obtained suggests that the frictional-ignition hazard with tungsten carbide tipped studs is in the same low range as the hazard from hobnails and other steel fittings to footwear (the National Coal Board (NCB, 1966) specifies a steel toe tip for boots that it purchases). Clearly, studs should not be used in conditions where hobnails and other steel fittings are not permitted.

5. USER EXPERIENCE

The work described in Section 2 was in hand during 1966. Early in 1967, the Doncaster Area of the National Coal Board issued some two hundred pairs of studded boots to surface workers in selected occupations. All the boots were standard miners' boots with direct-moulded soles and were in new condition. All were of the same type which, because it had large raised areas in the tread pattern, seemed the most suitable for studding. Twelve studs were inserted into each boot, seven in the sole and five in the heel.

SMRE followed the progress of this trial by periodically photographing the footwear of men who had been issued with studded boots. Most of the men were enthusiastic about the non-slip properties of the studs and did not find that the studs made the boots uncomfortable. On the whole, the studs remained in place remarkably well. Naturally, there were wide individual variations but, on average, studs were lost at the rate of one stud per ten or twelve weeks. Three years after being issued, some of these boots are still in use with more than half their studs present although the tread pattern has been worn smooth.

At the time of writing, Doncaster Area is undertaking a much larger trial in which nearly three thousand men are wearing studded boots, most of them previously-worn boots which their owners agreed to have studded. This experiment will be reported elsewhere, but the first results are promising from the point of view of

safety and acceptability. However, stud retention is not nearly as good as in the earlier experiment. This is not surprising since only just over a fifth of the boots in use were new when they were studded and since many types of boot have been studded, most of them not having many large raised areas in their tread patterns.

An independent Canadian experiment with tungsten carbide tipped studs in boots has been reported (Ramsay, 1967; Bechtel and Zieman, 1970). Their experience has been very similar to our own except that they report having had considerable trouble with studs pushing up through the soles. Since there has so far been only one such complaint arising from the tests undertaken by NCB, it seems likely that the boots used in the Canadian trials were less suitable for studding than those used in the British trials.

6. CONCLUSIONS

The use of a small number of small hard studs in footwear seems to be a promising development, but it is still in an experimental stage. Fitting studs which were designed for use in tyres to boots which were designed with no thought for studs is obviously a makeshift, although it is, at present, a convenient way for potential users to try out the idea with the help of their local garage.

Ideally, studs should be designed for use in footwear and should be put in during manufacture of the footwear. However, this might involve the manufacturers of both studs and footwear in expensive redesign work. Research work would also be needed on the stud retention characteristics of different sole materials, particularly oil-resisting materials since the studs perform so well in oily or greasy conditions.

A temporary compromise, which would not be costly and would avoid the relatively lengthy and trouble-prone process of drilling, would be to use standard tyre studs and to pre-mould holes for them in the soles and heels in the same way that holes for studs are moulded into some types of tyre. Certain British boot manufacturers are experimenting with pre-moulded holes.

Finally, it should be remembered that studs will not help unless they can bite right through any lubricating layer and into a solid substrate. Studs themselves will therefore not be useful in deep mud but it should be advantageous to use them in conjunction with a "chunky" tread pattern designed for use in deep mud.

ACKNOWLEDGMENTS

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